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The snakes of the flooded region of Itaparica hydroeletric dam, Northeastern Brazil: "development" based on the drowning of wildlife

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Abstract. The previously underestimated biodiversity of the Caatinga underwent a transformation with the emergence of new studies, intensifying interest in the biota of this complex dry forest. Studies on snakes from the Caatinga have increased recently, resulting in 112 recorded species. Contributing to this, we present a detailed list of 23 species rescued from the Itaparica reservoir implementation in the 1980s. Collected specimens are deposited in the Herpetological and Paleoherpetological Collection at the Universidade Federal Rural de Pernambuco. The recorded snake assemblage is typical of the dry Caatingas of the Sertaneja Depression. We discuss the impacts of flooding and specimen relocation without adequate planning or monitoring on snake diversity. Finally, we conclude by questioning the sustainability aspects of development and interventions in nature.

Key words. Assemblage, conservation, Serpentes, sustainability

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INTRODUCTION

In search of subsistence at any price, humans build dams on the main rivers in all continents, whether for electricity production, flood containment, or water storage for the driest seasons, among others. This practice has occurred since ancient times, but it needs to be rethought, as the impact onecosystems and the services they provide is enormous, especially on organsism with limited tolerance to changes, such as snakes. It is especially devastating in areas with well-marked seasonality, such as the semi-arid region of Brazil (Oliveira 2018).

The semi-arid region of Brazil represents an area of 969,589 km^2. Covering the north of Minas Gerais and most of the northeastern Brazilian states, except Maranhão, (MMA 2007; Pereira-Júnior 2007; Camardelli and Napoli 2012), it is characterized by an annual rainfall average which varies between 600 and 1,200 mm in most of the territory. The intense seasonal water shortages make the rainy period a sub-humid type and the dry period almost completely arid, with a dry season spanning five to seven months per year (Ab'Saber 1977). The Brazilian semi-arid region is quite heterogeneous in terms of its physical characteristics

and comprises almost the entire area of the Caatinga biome (MMA 2007; Camardelli and Napoli 2012). The Caatinga is recognized as a typical biome in the interior of the northeastern semi-arid region, and covers an area of approximately 852,261 km^2 (Ab'Sáber 1977; Prado 2003; Silva et al. 2017). The area of the Caatinga is comprised of different phytophysiognomy types of arboreal-shrubby vegetation, with high densities of woody plants, cacti, and hyper-xerophytic vegetation associated with rocky outcrops (Velloso et al. 2002).

For decades, the Caatinga has been described as a biome with low species richness and a low number of endemic species, with its reptile fauna composed of elements which occur in other open vegetation formations of South America (Vanzolini 1974; Vanzolini and Williams 1981; Vanzolini 1988). However, recently, the biome has been shown to be an important component of Brazilian biodiversity, with a significantly diversified fauna composed of endemic and threatened species (Rodrigues 2003; Leal et al. 2005; Albuquerque et al. 2012; Guedes et al. 2014; Pereira-Filho et al. 2017; Vieira et al. 2020). In this context, the study of snakes of the Caatinga has improved and there are currently 112 species recorded throughout the biome (Guedes et al. 2014).

Despite the Caatinga housing a great diversity of species, this biome suffers strong anthropogenic pressures throughout its range, mainly through habitat destruction via deforestation, fires, illegal hunting, and mining activity (Pereira-Filho et al. 2017). In addition to these human impacts, projects were implemented during the 1970s and 1980s to combat drought in Northeastern Brazil by generating electricity and implementing modern agricultural techniques using the waters of the São Francisco River (Silva and Santana 2020). Hydroelectric plants were built in the Brazilian states of Pernambuco and Bahia during this period, which had very significant socio-environmental impacts in the region (Silva and Santana 2020).

An example in the Brazilian semi-arid region is the Itaparica Hydroelectric Power Plant (HPP), also known as HPP Luiz Gonzaga, built by the Companhia Hidroelétrica do São Francisco (Chesf) between 1979–1988. The plant started operating at full capacity with six turbines in 1990, generating 1,500 MW of power (Codevasf 2022). The area flooded by the plant, known as Lake Itaparica, accumulates almost 11 billion m^3 of water and occupies an area of 83,400 hectares with 150 km^2 of extension in the states of Bahia and Pernambuco (Codevasf 2022). The formation of the lake had great impact on the region, as it resulted in the submersion of a large part of the Caatinga vegetation area and forced the resettlement of some 4,600 families (approximately 21,000 people) in the urban area and 5,900 (about 19,000 people) in the rural area, including 200 Indigenous families of the Tuxá tribe (Silva and Santana 2020).

In this context, the present study aims to contribute to the knowledge of the snake fauna of a Caatinga area from species rescued during the implementation of the Itaparica reservoir during the 1980s, as well as to examineif the rescue procedure is adequate for situations of such marked transformation.

STUDY AREA

The study was conducted in the municipality of Petrolândia, located in the state of Pernambuco, Northeast Brazil (08°58′53″S, 038°13′07″W). The region has a territorial extension of 1,056,589 km^2 (IBGE 2022) and is located in the São Francisco River basin. It is located in the Caatinga biome, where the predominant vegetation has xerophytic characteristics and a hot semi-arid climate of the BSh type, according to the Köppen-Geiger climate classification, which can be characterized by the scarcity of rainfall and great irregularity in its distribution, high evaporation rates, high average temperatures (~25 °C), and low relative humidity (Parahyba et al. 2004).

METHODS

Data source. All the specimens examined were rescued during the flooding of the municipality of Petrolândia in Pernambuco state in Northeastern Brazil (Figure 1); a city that was completely flooded during the implementation of the Luiz Gonzaga Hydroelectric Power Plant (Itaparica). Some other records, specifically the species *Chironius exoletus* (Linnaeus, 1758), *Spilotes pullatus* (Linnaeus, 1758), *Tantilla melanocephala* (Linnaeus, 1758), and *Helicops leopardinus* (Schlegel, 1837) were recorded in the Ilha de Paulo Afonso, a very close site with available data on the snake fauna; thus, we decided to add these records to the Itaparica species list. All the specimens were examined by authors GAPF and MAF, and the identity of the material was confirmed using specific literature (Vanzolini et al. 1980; Peters and Orejas-Miranda 1970; Campbell and Lamar 2004; Pereira-Filho et al. 2017) and through consultation with regional Herpetological collections of Universidade Federal da Paraíba (CHUFPB) and Universidade Federal Rural de Pernambuco (CHP-UFRPE), where specimens were compared with the material of both herpetological collections. The taxonomic arrangement followed Zaher et al. (2009) and Costa and Bernils (2018). All specimens were deposited at the Herpetological and Paleoherpetological collection of Universidade Federal Rural de Pernambuco (CHP-UFRPE). The methodology used to rescue the animals was led by Z.M.B. Morais and consisted of a single expedition lasting approximately one month in November 1988 (dry season). The rescuers investigated the whole area of the Itaparica lake using a boat during the day and night, searching for animals swimming or sheltered in rocks and trees. The rescuers also investigated the boards of the reservoir to capture animals

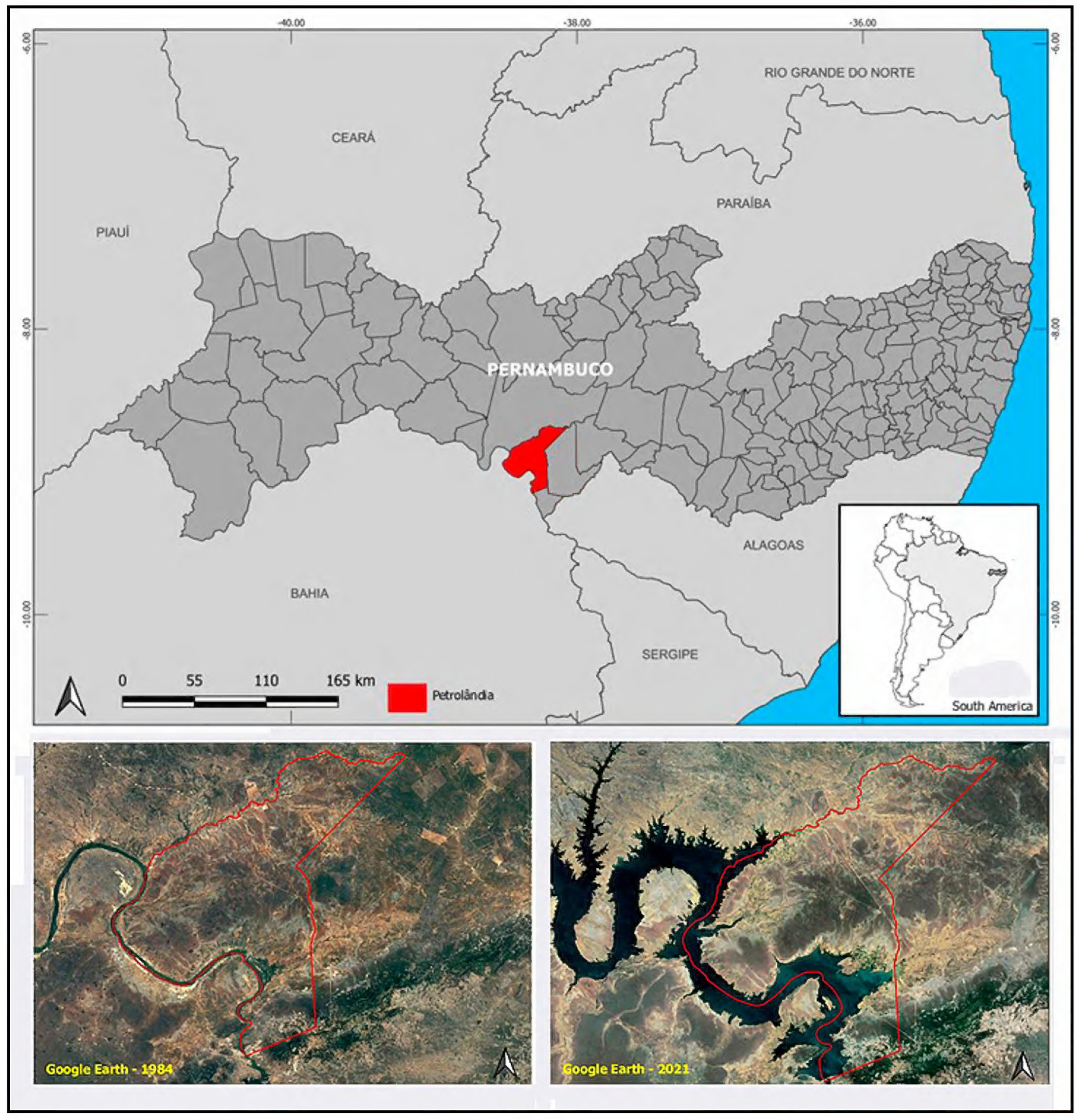

Figure 1. Upper map: location of the municipality of Petrolândia in Pernambuco state, Northeastern Brazil. Bottom images: On the left, the São Francisco River with its natural shape in the year of 1984. On the right, the São Francisco River wider and the Itaparica Lake, with the margins of Caatinga completely flooded in the year of 2002. Red line represents the limits of Petrolândia municipality.

which reached the board of the lake. The snakes were specifically rescued by hand and accommodated in wooden boxes. The animals found dead were deposited in the above mentioned herpetological collections. The living specimens were released on the Ilha de Paulo Afonso, a location close to the Petrolândia municipality. The reptile fauna of Ilha de Paulo Afonso was investigated months before the flooding of the area, and all the species released in the area were already known from Paulo Afonso, thus eliminating the risk of introducing exotic species in the area.

RESULTS

During the rescue in the flooded area of the Lake Itaparica formation, in the municipality of Petrolândia, we recorded 19 species of snakes representing 5 families (Boidae, Elapidae, Viperidae, Colubridae and Dipsadidae). Furthermore, we also rescued the species *Chironius exoletus* (Linnaeus, 1758), *Spilotes pullatus* (Linnaeus, 1758), *Tantilla melanocephala* (Linnaeus, 1758) and *Helicops leopardinus* (Schlegel, 1837) in the Ilha de Paulo Afonso region (Table 1).

Class Reptilia
Order Squamata
Family Boidae

***Boa constrictor* (Linnaeus, 1758)**
Figure 2A

Material examined. BRAZIL – Pernambuco • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 6 (sex indet.), CHP-UFRPE 5324, 5325, 5326, 5327, 328, 5329.

Identification. Specimens were identified by comparison with other examples deposited at the Herpetological collection of the Universidade Federal da Paraíba. We verified the presence of irregular and small scales on the top of the head as well as the presence of spurs in the cloacal region.

Table 1. Species recorded at Petrolândia flooded area, Pernambuco state, northeastern Brazil. D = diurnal, N = nocturnal.

Family, species	Number of individuals (%)	Activity
Boidae		
Boa constrictor (Linnaeus 1758)	5 (4.5)	D
Epicrates assisi (Machado, 1945)	3 (2.7)	D/N
Elapidae		
Micrurus bonita Nascimento, Graboski, Silva-Jr. & Prudente, 2024	10 (8.9)	N
Viperidae		
Bothrops erythromelas (Amaral, 1923)	1 (0.9)	N
Crotalus durissus Linnaeus, 1758	5 (4.5)	N
Colubridae		
Chironius exoletus (Linnaeus, 1758)*		D
Leptophis dibernardoi Albuquerque, Santos, Borges-Nojosa & Ávila, 2022	2 (1.8)	D
Oxybelis aeneus (Wagler, 1824)	4 (3.6)	D
Spilotes pullatus (Linnaeus, 1758)*		D
Tantilla melanocephala (Linnaeus, 1758)*		D
Dipsadidae		
Boiruna sertaneja Zaher, 1996	2 (1.8)	N
Erythrolamprus poecilogyrus (Wied, 1824)	9 (8.0)	D
Erythrolamprus viridis (Günther, 1862)	3 (2.7)	D
Helicops leopardinus (Schlegel, 1837)*		D/N
Leptodeira tarairiu Costa,Graboski, Grazziotin, Zaher, Rodrigues & Prudente, 2022	1 (0.9)	N
Philodryas olfersii (Lichtenstein, 1823)	11 (9.8)	D
Philodryas nattereri Steindachner, 1870	8 (7.1)	D
Oxyrhopus trigeminus Duméril, Bibron & Duméril, 1854	9 (8.0)	N
Pseudoboa nigra (Duméril, Bibron & Duméril, 1854)	8 (7.1)	N
Dryophylax almae (Franco & Ferreira, 2003)	8 (7.1)	N
Dryophylax phoenix (Franco, Trevine, Montingelli & Zaher, 2017)	6 (5.4)	N
Thamnodynastes sertanejo Bailey, Thomas & Silva-Jr., 2005	10 (8.9)	N
Xenodon merremii (Wagler, 1824)	7 (6.3)	D
Total individuals	**112**	

Species with * were not recorded in the flooded area of Petrolândia but in the Ilha de Paulo Afonso. Data on activity were gathered from Marques et al. (2017).

Epicrates assisi **(Machado, 1945)**
Figure 2B

Material examined. BRAZIL – Pernambuco • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 3 (sex indet.), CHP-UFRPE 5321, 5322, 5323.

Identification. Identified through the presence of irregular and small scales on the top of the head, presence of spurs in the cloacal region and the presence of labial pits.

Family Elapidae

Micrurus bonita **Nascimento, Graboski, Silva-Jr. & Prudente, 2024**
Figure 2C

Material examined. BRAZIL – Pernambuco • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 13 (sex indet.), CHP-UFRPE 5293, 5294, 5295, 5296, 5297, 5298, 5299, 5300, 5301, 5302, 5348, 5349, 5350.

Identification. Identified by the triadal color rings, short head, small eyes, dorsal scales of the first white ring without black margins, white snout, and mainly by the proteroglyphous dentition, a specific characteristic of this family.

Figure 2. Snakes recorded in the flooded area of Petrolândia: **A.** *Boa constrictor*. **B.** *Epicrates assisi*. **C.** *Micrurus bonita*. **D.** *Bothrops erythromelas*. **E.** *Crotalus durissus*. **F.** *Chironius exoletus*. **G.** *Leptophis dibernardoi*. **H.** *Oxybelis aeneus*. **I.** *Spilotes pullatus*. **J.** *Tantilla melanocephala*. **K.** *Boiruna sertaneja*. **L.** *Erythrolamprus poecilogyrus*. **M.** *Erythrolamprus viridis*. **N.** *Helicops leopardinus*. **O.** *Leptodeira tarairiu*. **P.** *Philodryas olfersii*. **Q.** *Philodryas nattereri*. **R.** *Oxyrhopus trigeminus*. **S.** *Pseudoboa nigra*. **T.** *Dryophylax almae*. **U.** *Dryophylax phoenix*. **V.** *Thamnodynastes sertanejo*. **W.** *Xenodon merremii*. Species recorded in the Ilha de Paulo Afonso are *Chironius exoletus*, *Spilotes pullatus*, *Tantilla melanocephala*, and *Helicops leopardinus* The images are of specimens found in the location close to the study area, and these were not collected and deposited in collections. Photos by Marco Antônio de Freitas.

Family Viperidae

***Bothrops erythromelas* (Amaral, 1923)**
Figure 2D

Material examined. BRAZIL – PERNAMBUCO • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 1 (sex indet.), CHP-UFRPE 5335.

Identification. The presence of a loreal pit, the solenoglyphous dentition, and absence of the rattle were the main characters used to identify this species.

***Crotalus durissus* Linnaeus, 1758**
Figure 2E

Material examined. BRAZIL – Pernambuco • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 5 (sex indet.), CHP-UFRPE 5330, 5331, 5332, 5333, 5334.

Identification. The presence of a loreal pit, the rattle, and the solenoglyphous dentition were the main characters used to identify this species.

Family Colubridae

***Chironius exoletus* (Linnaeus, 1758)**
Figure 2F

Material examined. BRAZIL – Pernambuco • Paulo Afonso; 09°24′02″S, 38°13′35″W; Nov. 1988; Z.M.B. Morais leg.; 1 (sex indet.), CHP-UFRPE 5400.

Identification. Identification based on the number of scale rows in the midbody (12 scales), long tail, and aglyphous dentition.

***Leptophis dibernardoi* Albuquerque, Santos, Borges-Nojosa & Ávila, 2022**
Figure 2G

Material examined. BRAZIL – Pernambuco • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 1 (sex indet.), CHP-UFRPE 5397, 5398.

Identification. Identification based on the scale row in the midbody (15 scales), long tail, black longitudinal stripe on the sides of the head, and the aglyphous dentition.

***Oxybelis aeneus* (Wagler, 1824)**
Figure 2H

Material examined. BRAZIL – Pernambuco • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 5 (sex indet.), CHP-UFRPE 5383, 5384, 5385, 5386, 5387.

Identification. The extremely elongated head was the main feature used to identify this species. The long tail and 17 scale rows in the midbody confirmed the identification.

***Spilotes pullatus* (Linnaeus, 1758)**
Figure 2I

Material examined. BRAZIL – Pernambuco • Paulo Afonso; 09°24′02″S, 038°13′35″W; Nov. 1988; Z.M.B. Morais leg.; 1 (sex indet.), CHP-UFRPE 6952.

Identification. This large snake was identified by the black and yellow dorsal coloration, long tail, and aglyphous dentition.

***Tantilla melanocephala* (Linnaeus, 1758)**
Figure 2J

Material examined. BRAZIL – Pernambuco • Paulo Afonso; 09°24′02″S, 038°13′35″W; Nov. 1988; Z.M.B. Morais leg.; 1 (sex indet.), CHP-UFRPE 6953.

Identification. Identified based on the small size, opisthoglyphous dentition, black cephalic hood, and black nuchal ring.

Family Dipsadidae

***Boiruna sertaneja* Zaher, 1996**
Figure 2K

Material examined. BRAZIL – Pernambuco • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 2 (sex indet.), CHP-UFRPE 5393, 5394.

Identification. - 19 scales rows in the midbody, entirely black dorsal coloration. White yellowish coloration in the anterior portion of the venter and blackish coloration in the posterior part.

***Erythrolamprus poecilogyrus* (Wied, 1824)**
Figure 2L

Material examined. BRAZIL – Pernambuco • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 11 (sex indet.), CHP-UFRPE 5403, 5404, 5405, 5406, 5407, 5408, 5409, 5410, 5411, 5412, 5413.

Identification. Identified based on the white venter, aglyphous dentition, and dorsal scale rows in 19-19-15.

***Erythrolamprus viridis* (Günther, 1862)**
Figure 2M

Material examined. BRAZIL – Pernambuco • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 3 (sex indet.), CHP-UFRPE 5414, 5415, 5416.

Identification. Identified based on the uniform dorsal green coloration and the completely white venter.

***Helicops leopardinus* (Schlegel, 1837)**
Figure 2N

Material examined. BRAZIL – Pernambuco • Paulo Afonso; 09°24′02″S, 038°13′35″W; Nov. 1988; Z.M.B. Morais leg.; 1 (sex indet.), CHP-UFRPE 6954.

Identification. Identified based on the eyes in the top of the head, valvular nostrils (adaptation to aquatic habits), and triangular frontal scale.

***Leptodeira tarairiu* Costa, Graboski, Grazziotin, Zaher, Rodrigues & Prudente, 2022**
Figure 2O

Material examined. BRAZIL – Pernambuco • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 1 (sex indet.), CHP-UFRPE 6955.

Identification. Identified based on the opisthoglyphous dentition, white venter, dorsum with brown spots distributed regularly, and vertical pupil.

***Philodryas olfersii* (Lichtenstein, 1823)**
Figure 2P

Material examined. BRAZIL – Pernambuco • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 12 (sex indet.), CHP-UFRPE 5336, 5337 5338, 5339, 5340, 5341, 5342, 5343, 5344, 5345, 5346, 5347.

Identification. The uniform green coloration in the dorsal and ventral region is an exclusive characteristic of this species.

***Philodryas nattereri* Steindachner, 1870**
Figure 2Q

Material examined. BRAZIL – Pernambuco • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 8 (sex indet.), CHP-UFRPE 5303, 5304, 5305, 5306, 5307, 5308, 5309, 5310.

Identification. The combination of characters such as brown dorsum and dorsal scale rows in 21-21-17 allowed us to identify this species.

***Oxyrhopus trigeminus* Duméril, Bibron & Duméril, 1854**
Figure 2R

Material examined. BRAZIL – Pernambuco • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 8 (sex indet.), CHP-UFRPE 5351, 5352, 5353, 5354, 5355, 5356, 5357, 5358.

Identification. The dorsal coloration with red, white, and black rings, white venter, and 19 scale rows in the midbody allowed us to identify this species.

***Pseudoboa nigra* (Duméril, Bibron & Duméril, 1854)**
Figure 2S

Material examined. BRAZIL – Pernambuco • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 9 (sex indet.), CHP-UFRPE 5311, 5312, 5314, 5315, 5316, 5317, 5318, 5319, 5320.

Identification. The single subcaudal scales and the dorsal black color were the main features to identify this species.

***Dryophylax almae* (Franco & Ferreira, 2003)**
Figure 2T

Material examined. BRAZIL – PERNAMBUCO • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 3 (sex indet.), CHP-UFRPE 5380, 5381, 5382.

Identification. Identified based on the white venter of the head, vertical pupil, brown dorsum, and ventral region with four longitudinal lines.

***Dryophylax phoenix* (Franco, Trevine, Montingelli & Zaher, 2017)**
Figure 2U

Material examined. BRAZIL – PERNAMBUCO • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 11 (sex indet.), CHP-UFRPE 5359, 5360, 5361, 5362, 5363, 5364, 5365, 5366, 5367, 5368, 5369.

Identification. 19 scale rows in the midbody, darkish venter of the head, and supralabial scales with white spots.

***Thamnodynastes sertanejo* Bailey, Thomas & Silva-Jr., 2005**
Figure 2V

Material examined. BRAZIL – PERNAMBUCO • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 10 (sex indet.), CHP-UFRPE 5370, 5371, 5372, 5373, 5374, 5375, 5376, 5377, 5378, 5379.

Identification. Identified based on 17-17-11 dorsal scale rows, opisthoglyphous dentition, and mixed pattern of distinct lines on its belly.

***Xenodon merremii* (Wagler, 1824)**
Figure 2W

Material examined.BRAZIL – PERNAMBUCO • Petrolândia; 08°58′53″S, 038°13′07″W; Nov. 1988; Z.M.B. Morais leg.; 9 (sex indet.), CHP-UFRPE 5311, 5312, 5314, 5315, 5316, 5317, 5318, 5319, 5320.

Identification. Identified based on 19 scale rows in the midbody, dorsal scales with apical pits, and 2 or 3 subocular scales.

DISCUSSION

The snake fauna recorded at Petrolândia on the occasion of the flooding and formation of Itaparica Lake is a typical snake assemblage of the Depressão Sertaneja Setentrional ecoregion, with some endemic species of Caatinga such as *Micrurus bonita*, *Bothrops erythromelas*, *Dryophylax almae*, *Dryophylax phoenix*, and *Thamnodynastes sertanejo* (Marques et al., 2017; Vieira et al. 2020) (Table 1). Other species, such as *Boiruna sertaneja*, *Epicrates assisi*, *Crotalus durissus*, and *Leptodeira tarairiu*are mainly present in the semi-arid Caatinga, but can also be found in transitional zones between Caatinga and the Northern Atlantic Forest (Pereira-Filho et al. 2017; 2021). Considering the species richness recorded during the rescue (19 species), the snake population of the Caatinga in the municipality of Petrolândia can be considered rich and similar in terms of composition when compared with well sampled areas like Fazenda Almas (22 species in Paraíba state) (Vieira et al. 2020), Pentecostes (22 species in Ceará state) (Mesquita et al. 2013), and São João do Cariri (14 species also in Paraíba state) (Pereira-Filho et al. 2017). The richness in the ecoregions of the Caatinga, specifically in the Depressão Sertaneja Setentrional varies from 14 to 22 species, and the 19 species recorded in Petrolândia attests to a rich assemblage in the area. Our species list comes from dead specimens found during the rescue procedure. It is possible that the snake assemblage of the region was once richer as some typical species of the Caatinga were not recorded, such as *Epictia borapeliotes* (Vanzolini, 1996), *Apostolepis cearensis* Gomes, 1915, both fossorial species, and *Lygophis dilepis* (Cope, 1862). Unfortunately, this information is completely lost.

This specific database on the snakes of Itaparica Lake comes with many concerns, considering the idea of further developing areas in Northeastern Brazil. The first question that comes to mind is: how was the snake population affected by the flooding of the area? This question is impossible to ask appropriately, especially after more than 30 years since the implementation of the reservoir. The flooding of the area, at minimum, extinguished a rich snake assemblage, typical of the core area of the Caatinga (seasonally dry tropical forest and woodlands). The total area that is now completely submerged covers a large range of different vegetation types and natural habitats which were once fundamental for the high richness of snakes recorded (Figure 1). A second question that is impossible to be answered is: did the rescue save a viable number of individuals?. It is also impossible to know if the amount of released specimens represented a good share of the original populations, nor is it possible to know how many specimens drowned during the flooding process. Unfortunately, there is no information about the number of specimens and species released, which is crucial information. A third question is: after the release of the specimens in the

Ilha de Paulo Afonso, were they monitored in order to verify if the release was successful and if it really rescued these animals, or simply delayed their demise? At the occasion, there was no monitoring program of the rescued animals. Considering they were released in a new area, many aspects must be considered. Can the released place harbor the number of new individuals? Will the new individuals compete with the local population? Were the released individuals healthy, in order to avoid dissemination of diseases and parasites to the local population? All of these questions must be considered for an adequate rescue and release program (Rodrigues 2006).

After all the problems and questions mentioned above and using the situation presented herein as a model, it is imperative to point out possible solutions for the faunal rescue issue. Facing scarce bibliography about the theme, some procedures must be adopted in every rescue program. The first is to establish a monitoring program aiming to observe the released animals, verifying if the individuals were able to establish territories, find sources of water and food, and finally were able to procreate. All the releases must be under the supervision of veterinarians to attest to the health of the specimens. Finally, part of the rescued fauna must be deposited in biological collections (vouchers and samples of tissues in order to sample the genetic variability), and we can point out two main reasons for this. The first is that biological material of the species of the flooded area is essential and works as a testimony of the drowned richness of the affected area. The second reason is that even with the monitoring program, there is no guarantee of success of the rescued individuals in the new natural habitat; if the program is unsuccessful, it is fundamental to have specimens deposited in biological collection serving one more time as testimony of the biodiversity of the area (Rodrigues 2006). We do believe that without a monitoring program and the a choice of a well-structured release area with abundant resources, the release of the rescued fauna is not an appropriate option. We also believe that the flooding of natural areas similar to what happened in Petrolândia is unacceptable and must not be repeated in any place. The development based on the destruction of wildlife is a misleading tale, an uncertain decision without guarantees of success and an environmental massacre without a second chance for many affected species. Finally, it is impressive that we were not able to find any scientific publication regarding the effect on the fauna or flora of the area even 40 years before the flooding, perhaps because the procedures of that time can be considered outdated and inadequate or due to the lack of data availability which did not enable major considerations about the impacts. The point is that this is the first scientific publication about a zoological group at that site and all the considerations made herein for the snake assemblage can also be generally applied to all other taxa such as mammals, amphibians, reptiles, and birds, since they all faced similar environmental problems. This is a faithful reflection of how Brazil conducted these environmental matters: an unclear process, without environmental studies in the area after the flood, and no partnership with the scientific community enabling studies even though all of the reservoir and the affected area could be considered a laboratory to evaluate similar processes further. The Itaparica Hydroelectric Power Plant case is an unfortunateexample of how not to conduct "development" claiming benefits for human populations while completely ignoring the impacts on the fauna and flora of Brazilian ecosystems.

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ADDITIONAL INFORMATION

Conflict of interest

The authors declare that no competing interests exist.

Ethical statement

No ethical statement is reported.

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Author contributions

Study conception: GAPF, FGRF, WLSV, ZMBM, GAAX, MAF, RRNA, GJBM. Data analysis: GAPF, FGRF, WLSV, AFFF, ZMBM, GAAX, MAF, RRNA, GJBM. Wrote the first draft of the manuscript: GAPF, FGRF, WLSV, ZMBM, GAAX, MAF, RRNA, GJBM. Wrote the final version of the manuscript: AFFF, GJBM. Supervision: GJBM

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Data availability
All data that support the findings of this study are available in the main text.

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